342.4
J. P. Kleen, Portland, Ore.

4

UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY

FOREST INSECT INVESTIGATIONS

SB
945
.B424
R92
1935

FINAL REPORT ON THE BIOLOGY OF IPS OREGONI AND ASSOCIATED INSECTS OF IDAHO

Henry J. Rust
Senior Scientific Aid

Forest Insect Laboratory
Coeur d'Alene, Idaho
February 27, 1935

U. S. GOVERNMENT PRINTING OFFICE: 1935 J 76122

FINAL REPORT ON THE BIOLOGY OF IPS OREGONI AND ASSOCIATED INSECTS OF IDAHO

Respectfully submitted,

Henry J. Rust

Henry J. Rust
Senior Scientific Aid

Forest Insect Laboratory
Coeur d'Alene, Idaho
February 27, 1935

Table of Contents

INTRODUCTION . . . . . 1 - 2

METHODS AND PROCEDURE. . . . . 2 - 3

THE OREGON ENGRAVER BEETLE . . . . . 4 - 34
- Range and Hosts 4
- Description of Stages . . . . . 4 - 5
- Development and Habits. . . . . 5 - 15
- Feeding or Resting Period . . . . . 15 - 16
- Hibernation. . . . . 17 - 18
- Seasonal History. . . . . 18 - 22
- Potential Brood and Emergence . . . . . 22 - 27
- Ratio of Emergence to Attack. . . . . 27 - 30
- Preferred Host Material . . . . . 30 - 34

CONTROL. . . . . 34 - 47
- Artificial Control. . . . . 34 - 35
- Natural Control . . . . . 35 - 36
- Arachnida . . . . . 36 - 39
- Coleoptera. . . . . 39 - 42
- Hymenoptera . . . . . 42 - 44
- Diptera 44
- Hemiptera . . . . . 44 - 45
- Aves. . . . . 46 - 47

ANNOTATED LIST OF INSECTS AND ARACHNIDA IN ASSOCIATION WITH IPS OREGONI . . . . . 48 - 56
- Coleoptera. . . . . 48 - 52
- Hymenoptera 53
- Hemiptera 54
- Diptera 55
- Arachnida 56

SUMMARY AND CONCLUSIONS. . . . . 57 - 61

PLATES . . . . . 62 - 71

FINAL REPORT ON THE BIOLOGY OF IPS OREGONI AND ASSOCIATED INSECTS OF IDAHO

INTRODUCTION

Artificial control measures against primary tree-killing bark beetles have been in use since 1905, but it is only within recent years that attention has been given to those species which are considered as being secondary in their attacks. As an example of the increasing importance of these insects, approximately 3000 small ponderosa pines infested with the Oregon engraver beetle (Ips oregoni Eichh) within the city limits of Spokane, Washington, were cut and burned in 1930, and in 1931, 2000 lodgepole pines along new highway construction in the Yellowstone National Park, Wyoming, were also treated because of an infestation of the same insect.

This tendency of secondary beetles to assume primary roles has resulted from the extensive cutting of timber for lumber, ties and cordwood, and in the construction of trails, roads and highways which has been in progress throughout the forested areas of the western states during the past ten years. All of the operations have produced large quantities of slash, fire-scorched and injured trees. This weakened material is sought out by the Oregon engraver beetle in which it breeds up in large numbers and then attacks and kills green standing trees.

Owing to the increasing number of outbreaks of secondary bark beetles, particularly the genus Ips, the writer has been assigned to the study of Ips oregoni and associated insects in the vicinity of Coeur d'Alene, Idaho, to secure data from which effective control measures might be developed as well as to isolate the factors causing the rise and decline of such outbreaks. Two progress reports were submitted covering information secured during each season, and this paper is presented as a final report of the study which was in progress during three full field seasons and part of a fourth.

METHODS AND PROCEDURE

During the course of this study, the Oregon engraver beetle and its associates were studied both through field observations and laboratory rearing. The field study included observation of infested logging and woodcutting slash, green standing trees, trap trees and fire-scorched areas representing a variety of exposures. On one of the areas fresh slash was available for attack throughout the entire season of bark-beetle activity, thus making it possible for an intensive study of the successive generation development. In another area trap trees were cut after bark-beetle activity had ceased in the fall, to ascertain if overwintering slash would be attractive the following year.

Practically all types of ponderosa pine slash were used in the study, from limbs 2 inches in diameter to cull logs and tops 6 to 18 inches in diameter. Limbed and unlimbed slash from cutting operations, trap trees, broken tops, windfalls, cordwood piled and unpiled and 16 inch wood with bark intact were included. On the burns, attacked standing trees showing all degrees of fire injury to crown and root collar were used for checking both development of brood and associated insects, as well as for rearing purposes.

The rearing cans used in the study were constructed of galvanized iron, with screened ventilation in the cover and a glass jar containing water, fastened to the sloping bottom. These cans had a capacity up to 16 square feet of bark surface and all emerging insects were secured in the glass jar. In all emergence was secured from a total of 161 square feet of attacked material.

The cages used in the study consisted of a light frame work of wood covered with fine wire screen, and measured four feet long, one foot wide and one foot deep. Freshly attacked material was placed in the cages each season and a check kept on brood and generation development and compared with activity in the field. Approximately 2000 lineal feet of all types of attacked slash were intensively examined in the field, 585 small fire scorched trees and 125 small green standing trees. In the determination of sex ratio by emergence and brood development, 25,000 adult Ips oregoni beetles were examined, the majority of which were secured from the rearing cans.

THE OREGON ENGRAVER BEETLE

Range and Hosts

The Oregon engraver beetle is classed as a very destructive secondary bark beetle and is common within a range extending from northwestern Canada to Mexico, and from the Dakotas to the Pacific Coast. This large area is the habitat of the ponderosa pine (Pinus ponderosa Lawson) which ranks first as a preferred host of this insect. Other pines in which this bark beetle is known to breed are lodgepole pine (Pinus contorta), Jeffrey pine (Pinus jeffreyi), Sugar pine (Pinus lambertiana), and Digger pine (Pinus sabiniana). Collections of adults and developing broods have also been made from the Black Hills spruce (Picea glauca albertiana) in South Dakota and Engelmann spruce (Picea engelmanni) in western Wyoming.

Description of Stages

Egg

The eggs are oval in shape pearly white in color, average .9 millimeters in length and .6 millimeters in width.

Larva

The larva is a small, white, legless grub with brown sclerotized head capsule and curved body. The average length of first instar larva is 1.8 millimeters, the second instar larva 2.5 millimeters, and the third from 4.3 millimeters to 4.9 millimeters.

Pupa

The pupa is white, shining with a bified process on the apex of the abdomen. The average size is 4.2 millimeters long by 1.6 millimeters in width.

Ips oregoni was originally described by Eichhoff in "Berliner Entomologischi Zeitshrift" in 1868 and only a brief description is included. In the early stages of development, the color of the adult is a yellowish tan gradually turning to a yellow brown, then to a dark reddish brown with a final development to a shining black. The adult beetles are cylindrical in form and average 4.1 millimeters in length and 1.6 millimeters in width. Both the male and female beetles have four spines on the margin of the elytral declivity, the male being readily distinguished from the female by the greater length of the third spine. (See Plate 1, figures 4 and 5.)

Development and Habits

Attack

The attack is made by the male beetle which bores through the outer bark at an upward angle varying from 25 to 45 degrees into the inner layer of growing tissue lying next to the wood. Boring dust is pushed out of the entrance hole and accumulates in a small pile on the surface of down slash, whereas on standing trees it sifts down over the outer bark to the ground. A small chamber averaging

8 millimeters in length and 6 millimeters in breadth is excavated in the inner bark and partly scores the wood. These excavations or nuptial chambers are sought by female beetles and the number of females attracted to each new attack apparently determines the number of branches or egg galleries radiating from the nuptial chamber which may vary from 1 to 7 with an average of 3 for all attacks. (See Plate 2, Figures A, B, and C.)

Mating and Sex Ratio

Being a polygamous species, mating first occurs in the nuptial chamber, however, later matings may occur in the egg galleries. The proportion of female to male beetles is one of the most important phases of development because being polygamous, the survival of a greater number of females is apparently necessary for the perpetuation of the species. Three different methods were used during the study to determine the sex ratio of the adult beetles: (1) Opening up new attacks after egg gallery construction had started and counting the number and sex of the parent adult beetles present. This method also gave a record of the number of egg galleries for each attack. (2) By examining the emerged parent adults secured from attacked material in rearing cans. (3) By counting the number of egg galleries for each attack in a large number of attacks. Briefly, all of these methods showed the sex ratio in attacks to be 3 females to 1 male, whereas in newly emerged adults there were only 1.2 females to every

male. Although there was a slight variation in the ratio for the various generations and seasons, it was quite constant and averaged close to the general average. In glancing over a small amount of attacked material, the wide variation from one to seven egg galleries per attack becomes apparent, but the average number of galleries can only be secured from examinations of a large number of attacks.

In 1932, 579 hibernating adults were collected from the inner bark of small ponderosa pine stumps, (See Plate 3) and were liberated in two separate cages. In one cage, 200 adults were liberated in a ratio of 1 female to 1 male and in the other, 288 beetles were liberated in a ratio of 3 females to 1 male to determine the effect of sex ratio upon the number of egg galleries produced per attack. This experiment gave the following results:

Table I.

EFFECT OF SEX RATIO ON NUMBER OF EGG GALLERIES PER ATTACK

Sex ratio	No. & sex of adult beetles used		No. & % of males attacking	No. & % of females attacking	Egg gallery branches per attack in percent				
	female	Male			1	2	3	4	5
1 to 1:	100	100	49 - 49%	86 - 86%	45	41	10	2	2
3 to 1:	216	72	68 - 89%	194 - 90%	0	26.5	48.4	20.4	4.7

This experiment showed that the sex ratio of 3 females to 1 male resulted in a number of egg galleries per attack very close to the number found in actual field conditions. In cage 2, 48.4 percent of the attacks contained 3 egg galleries, which closely

approximates the 53 percent under normal conditions. The 1 to 1 ratio resulted in only 10 percent of the attacks having 3 egg galleries, failed to produce as many attacks, the length of egg gallery was less and brood potential was lower than found under cage and field conditions with the ratio of three to one. The most noticeable effect which the ratio of one to one had, was the larger percentage of attacks containing but one and two egg galleries. Field observations during three seasons showed that there is a heavy mortality to the male beetles during the time between emergence and the finished entrance hole, which accounts for the unequal sex ratio found in attacked material. While crawling about over the outer bark surface prior to the start of the entrancehole and during the excavation of the nuptial chamber, the male beetle is exposed to a number of predacious enemies such as birds, ants, clerid beetles and wasps. The capture and destruction of male beetles by these predators has been observed repeatedly, especially during the attack period of the third and fourth generations. The female beetles escape much of this danger as the new attack appears to be readily located and immediately accessible through the open entrance.

Egg Gallery Construction

Soon after entering the nuptial chamber, egg gallery construction is started by the female beetle. In some instances this begins before the nuptial excavation has been completed by the male and tends

to cause the very irregular forms of these chambers which are often recorded. (See Plate 2, Figure B.) In studying a large number of egg gallery patterns, it becomes apparent that in nearly all cases, one egg gallery is constructed directly opposite the entrance hole which leads into the nuptial chamber. This is usually the first start of egg gallery construction and has a tendency to determine the arrangement of additional galleries. The completed group is so arranged that the bulk, if not all, of the frass or borings from the egg galleries passes from the gallery entrance into the nuptial chamber without blocking the entrances of the surrounding galleries. The greatest advantage of this feature occurs in standing trees because the frass from the galleries, upon being ejected, naturally drops into the opening of the entrance hole and is there easily pushed to the outside. (See Plate 4, Figure E. The galleries are tunneled in the living tissues between the bark and the wood, which, being slightly less than the thickness of a beetle, results in a slight grooving of the wood. The number of egg galleries per attack depends to a great extent on the number of beetles present or attacted to an area and also on the size and exposure of the attacked material. As had been stated, the number of galleries may vary from one to seven, one six and seven being rare exceptions. Attacks with but one or two egg galleries usually occur during the first and

second generations and are generally found on the under side of the larger slash. They are indicative of either a dwindling in attacks from the more exposed tops or sides, or a distaste for the densely shaded portions of the log. Attacks with 5, 6 and in extreme cases 7 egg galleries, are found on the heavier attacked, more exposed portions. (See Plate 5) The results of examinations during three seasons gave an average of 53 percent of the attacks with 3 egg galleries, 27 percent with 4, 5 percent with 5 galleries and the remaining 15 percent divided among those with 1, 2, 6 or 7.

The general trend of each egg gallery is with the grain of the wood both above and below the nuptial chamber. The rapidity of construction depends to a great extent on the gravidness of the female beetles and the prevailing bark temperature. Enough gallery is made rapidly to accommodate the first batch of from 2 to 9 eggs and usually 3/8 of an inch is constructed before any eggs are deposited. (See Plate 2, Figures C and D.) The speed of egg gallery construction also varies with the different generations, 3/4 of an inch being constructed in 2 days during the first generation in April and 1½ inches in 2 days by the third and fourth generations during July and August. The average total length of egg gallery per attack was found to be 10½ inches for the first three generations and 7½ inches for the fourth and fifth when present. The amount of egg gallery construction depends upon the density of the attack, the amount of available space, bark temperatures and the number of eggs to be laid by the female beetle. Egg

niches, measuring slightly over one millimeter in depth and a little longer than the egg, are cut along the sides of the egg gallery. After placing the egg in position, the female beetle constructs a plug of frass approximately.5 millimeters thick which is forced into the remaining space of the egg niche completely sealing the opening. These frass plugs are grooved on the outside to conform to the cylindrical shape of the gallery, and as the entrance of the nuptial chamber is open and the egg gallery kept free from frass, they are the only protection the eggs have from the multitude of associated insects which are found in the nuptial chamber and egg galleries. The eggs may be deposited in single niches or in groups of niches separated by thin walls or partitions. The removal of frass from the nuptial chamber and egg galleries, while affording easy access to the associated insects, has beneficial advantages as well, such as facilitating additional matings, preventing mould or fungus growth, and providing ventilation. There are also branch excavations, commonly known as ventilation holes, cut from the roof of the egg gallery through a portion of the outer bark. These holes average 2 millimeters in diameter and from 4 to 6½ millimeters in depth depending on the thickness of the bark. They occur singly or in pairs spaced 4½ millimeters from center to center and are used as turning places as well as for ventillation. In 42 percent of the egg galleries examined these paired holes occurred near the nuptial chamber and were usually followed by one or more single excavations further along the roof of the gallery.

Incubation Period

The duration of time elapsing from egg deposition to incubation is governed by the prevailing bark temperature and varies from 4 to 12 days or more.

Larval Development

Soon after hatching the larva starts feeding on the inner layer of tissue in which the egg has been placed. (See Plate 2, Figure D.) This is the beginning of the larval mine and as feeding continues the tunnel is developed at a right angle to the egg gallery generally continuing in this direction across the grain of the wood. The length and direction of the completed larval mine varies according to the spacing of competitive egg galleries which practically govern the limits of the food supply. As the larva progresses, the unconsumed cuttings and excrement are packed solidly in the mine behind the larva, thus affording protection by preventing immediate access of its many enemies.

The duration of the larval feeding period depends to a great extent on the prevailing bark temperatures and moisture content. Three instars occur during the larval stage, the first takes place from 2 to 6 days after hatching when the larval mine has been extended from 1/4 to 1/2 inch. Feeding is resumed shortly after the ecdysis and the larval mine extended for from 4 to 8 days when the second

ecdysis occurs. The third and final moult is accomplished in the pupal chamber from 2 to 4 days after the second.

The larva mine increases in diameter with the growth of the larva. With the thicker inner layer of tissue in ponderosa pine, grooving of the wood by the larva rarely commences before the completion of the second instar; at this time the larva mine has usually increased in diameter beyond the thickness of the feeding tissue. With the thin-barked species of pine such as lodgepole, grooving of the wood begins soon after the larval mine is started. At the cessation of feeding prior to each ecdysis, a slight enlargement of the larval mine is noticeable, the pupal cell serving for the last moult.

The pupal cell is slightly oval in shape, varying from 2 to 3 millimeters in depth and from 5 to 6 millimeters in diameter at the widest part. This cell is constructed partly in the bark and partly in the wood, the depth depending on the thickness of the bark. The shape is governed by the actions of the larva as it twists about while feeding. The entrance to the pupal chamber is packed solidly with frass. Upon the completion of the cell, the larva discontinues feeding, the intestinal tract is voided, a contraction takes place, the larva becomes practically motionless, lustrous white in color, and the transformation to the pupa occurs.

Pupa

The length of the pupal stadium lasts from 2 to 12 days or more. It is during the pupal stage that many of the larger predacious

larvae, such as the Clerids, find easy access through the dividing walls of the cells. This entrance made by the Clerid larvae opens up the way for numerous other smaller predacious enemies resulting in considerable mortality to the pupae.

The pupal stadium in the fourth generation occurring from the latter part of September until the middle of October is greatly lengthened, particularly in slash, owing to air temperatures below 60° F. Should the low temperatures continue for any length of time, the transformation to new adults fails to take place, and the pupae die, thus causing a very heavy loss to the potential brood.

New Adults

The new adults develop rapidly and as soon as they are able to move about freely in the pupal cell, begin boring either through the dividing wall or into the outer bark. When the walls of the pupal cells are broken down a number of the new adults congregate so that if much feeding is done a considerable area of the inner bark layer is eaten away and emergence of a group of new adults may take place through only one or two holes. When isolated in pupal cells or outer bark, new adults bore individual emergence holes. The color development of the adults extends over a period of weeks. Sexual maturity is undoubtedly reached independently of the color development, as many breeding adults still in the yellow brown color stage were found in attacks, in some instances constituting 76 percent of the total adults present.

Emergence

Emergence of new adults is subject to considerable variation in time, depending to a great extent on bark temperatures. Those on the upper portions of slash exposed to sunlight emerge much sooner than those on the under side of logs and slash, and the emergence from standing trees is more rapid in the upper portion exposed to the light and heat. Variations are also caused by a difference in the time of development from the first eggs laid in the egg gallery to those laid at completion of the gallery. It has also been found that new adults developing from the third generation attacks in slash will feed on the inner bark tissue for a considerable length of time before emerging. These irregularities in emergence also affect the periods of new attacks for the different generations prolonging them in the same proportion

Feeding or Resting Period

In the infested material containing the third, fourth and fifth generation when present, a much heavier attack then necessary to produce an average brood has often been found to occur. The normal average of 24 attacks per square foot has been found to increase to 49 or more and adults from the average 96 to 500 or more. At the close of the 1931 season, it was thought that this crowding of adults was due to the lack of preferred host material, but additional observations made during the 1932-33 seasons have disproved this because the concentration has been found to occur in areas with an abundance of typical host

material. Observations during the three seasons have shown definitely that there is a period beginning with the third and increasing during the fourth and fifth generations when egg-laying activity lessens. This reduction in productiveness is also represented by a decrease in the average potential brood per square foot during these last generations.

The activities of the excess beetles appear to be mostly confined to constructing short tunnels in the inner bark layer radiating in all directions from the point of attack. From these short tunnels feeding is carried on to a considerable extent, in some cases consuming the entire inner bark surface. This loss of available food supply for the developing larvae causes a very heavy brood mortality. (See Plate 6.) Where the concentration of beetles has been sufficient to eat out the entire inner bark surface, they often emerge and concentrate in the tops of larger ponderosa pine trees where feeding activities as well as some egg gallery construction may extend for 15 or 30 feet from the extreme top down through the thinner barked portion of the attacked tree. After these top portions are killed, they are usually known as spike tops and can be found in ponderosa pine stands throughout the range of the Oregon engraver beetle.

This crowded condition of adult beetles was found to occur usually during a period of maximum air temperatures from 80° to 92° F., with bark temperatures ranging from 90° to 103°. This excessive heat may be the cause for the reduction in brood potential as well as reproduction inactivity.

Hibernation

The hibernation period of Ips oregoni begins with the advent of heavy frosts when the daily maximum temperatures average below 50° F., which occurred on November 7 in 1931. With more normal seasons such as 1932 and 1933, hibernation started on October 21 and October 18 respectively. Hibernation lasts throughout the winter until temperatures reach 68° F., which usually occurs between the 10th and 20th of April in the vicinity of Coeur d'Alene, Idaho. The adult beetles hibernate in all types of material such as trees containing the last generation broods, the larger slash, stumps in which adult beetles have been found in the inner bark layer from a few inches below the top edge of the bark to three or four inches below the ground level, (See Plate 3) and in the egg galleries of the western pine beetle. Those found in the last-named material average 18 adult Ips oregoni per square foot and in trees 30 to 40 inches d.b.h., this average represents a large number of hibernating adults afforded added protection from low temperatures by the thick bark.

Total inactivity of the adult beetles apparently follows a short feeding period as shown by the short feeding tunnels in the inner bark layer surrounding the groups of adults present, these groups varying in number from 2 to 100 beetles or more.

The ability of the adult beetles to continue active throughout the growing season, hibernate for the winter, re-emerge and

resume activity the following season accounts in a large measure for the continued presence of large numbers of the Ips oregoni beetles throughout its range.

Seasonal History

As temperature and moisture are the dominating factors determining the duration of the developmental periods, variations are found to occur not only in the time required for the development of a generation, but also in the number of generations per season. The word "season" as used in this report has reference to the period of bark beetle activity beginning with the first attacks in April and ending with the cessation of activity in November. This period of activity is comparable to the season of plant activity beginning with the swelling or bursting of leaf buds on deciduous shrubs in April and ending with the falling of the leaves in November. The period of attack for each generation is often considerably prolonged expecially so with the first generation following a cold winter. Considerable hibernation has been found to occur in stumps and during severe winters such as 1932-33, many of the beetles tunneled into the inner bark below the ground level, and emerged in the spring much later than those from the portions of standing trees exposed to sunlight. The second generation attack period is considerably lengthened by the prolonged emergence of new adults developing in slash material particularly if emergence follows cool weather and heavy rainstorms.

In the vicinity of Coeur d'Alene, Idaho, 47°4' N. Lat., 116° W. Long., attacks from hibernating adults starting the first generation broods occur in April usually between the 10th and 20th. When the first generation broods have reached the new adult stage, the parent adults begin emerging, and attacking new host material to generate their second brood. This event is soon followed by emergence and attacks by the first generation new adults thus starting the second generation. As soon as the second generation broods have reached the new adult stage, their parents begin emerging to start another brood. The re-emergence by parent adults and follow-up attacks by new adults creates an attack period that is practically continuous throughout the season, and results in an overlapping of all the developmental stadia from eggs to new adults.

The following table gives a list of dates showing the time of life history events under favorable conditions as recorded during three and a half seasons. The data were secured by observations of material both in the field and in rearing cans and cages. The extreme variations in development and family relationships have been omitted.

Table II

PERIOD OF GENERATION DEVELOPMENT BY DAYS

Gen.	Attack	Eggs	Larvae	Pupae	N. A.	Emergence	Days from att. to emer.	
1931								
1	Apr. 16	Apr. 18	Apr. 30	May 17	May 21	June 1	45	
2	June 2	June 3	June 13	June 29	July 3	July 11	40	
3	July 11	July 12	July 16	July 27	July 29	Aug. 3	24	
4	Aug. 3	Aug. 4	Aug. 11	Aug. 22	Aug. 26	Sept. 2	31	
5	Sept. 3	Sept. 4	Sept. 14	Sept. 27	Oct. 1	Oct. 11	39	179
1932								
1	Apr. 13	Apr. 15	Apr. 27	May 24	June 5	June 18	66	
2	June 22	June 24	June 28	July 14	July 19	July 26	34	
3	July 27	July 29	Aug. 2	Aug. 16	Aug. 22	Sept. 2	37	
4	Sept. 4	Sept. 6	Sept. 18	Oct. 14	Oct. 21	--	47	184
1933								
1	Apr. 21	Apr. 23	May 4	May 25	June 5	June 18	58	
2	June 20	June 21	June 29	July 14	July 20	July 28	38	
3	July 29	July 30	Aug. 3	Aug. 17	Aug. 24	Sept. 2	35	
4	Sept. 3	Sept. 5	Sept. 13	Oct. 1	Oct. 10	Oct. 23	50	181
1934								
1	Apr. 6	Apr. 8	Apr. 20	May 7	May 15	May 29	53	

Four generations in 178 days.

Table II shows that for the spring of 1931 following an average winter the seasonal activity of Ips oregoni began with emergence of hibernating adults and attacks for the first generation on April 16. Air temperatures from the latter part of April to the middle of October 1931 were considerably above the normal or yearly average and with the exception of September and October, the rainfall was much below the yearly average. This season was exceptional for the development of Ips oregoni as five complete generations were produced, the gain of one generation over normal years being possible by the shortening of the developmental period of the first and second generations due to an increase of air temperatures during May and July. In 1932 a rapid rise in temperature on April 10 started the attack period, which became general by the 13th of the month. Air temperatures for May were considerably below the yearly average and with an increase in precipitation for April and May, the developmental period for the first generation of Ips oregoni was prolonged 21 days as compared with the same event for 1931. This increase of 21 days forced the developmental period for the second generation into a warm spell of weather resulting in a gain of six days as compared with the second generation in 1931. This gain, however, was lost during the third generation and the total result was but four generations for 1932. In the spring of 1933, following a severe cold spell, favorable temperatures for activity were not recorded until April 20th,

at which time attacks for the first generation commenced, becoming general on the 21st. The developmental period for the first generation was delayed 13 days as compared with 1931, and 8 days in advance of the 1932 period. In the spring of 1934 which followed an unusually mild winter, hibernating adults attacked slash on April 6, ten days earlier than in 1931, seven days earlier than 1932 and 15 days earlier than in 1933. This early start for the first generation in 1934 was overcome by heavy precipitation in April and May prolonging the period from attack to emergence to 53 days. An increase of eight days over 1931, but a decrease of 13 days under 1932 and 5 days under 1933. A summary of the developmental periods for the various generations during the four seasons, shows that while there may be a considerable variation in the duration of different events, the total period of activity from the first attacks in the spring until hibernation in the fall varies but slightly as five generations developed in 179 days in 1931; four generations in 184 days in 1932; four generations in 181 days in 1933; and four generations in 178 days in 1934. The average development period or length of seasonal activity for the four seasons was 180.5 days.

Potential Brood and Emergence

The number of lineal feet of egg gallery per square foot varies considerably. In 1931 there was an average of 21 feet for the first four generations, and only 16 lineal feet for the fifth. In 1932 the

second generation gave practically the same average as in 1931, and the third was comparable to the 5th generation in 1931. The first generation in 1933, following a very severe winter, only excavated 10½ lineal feet of egg gallery per square foot.

Using the average of 21 lineal feet of egg gallery per square foot and subtracting two lineal feet as the amount unoccupied by eggs, there are 19 feet of productive gallery. Applying the average of 72 eggs per lineal foot, there is a total potential brood of 1368 per square foot. All of the emergence data secured by the use of galvanized rearing cans during the three seasons is given in the following table and is compared with the average brood potential for each generation.

Table III

COMPARISON OF THE POTENTIAL BROODS WITH EMERGENCE FOR THE SEASONS OF 1931, 1932 & 1933.

Type of host material	No.sq.ft. bark surface	Gener-ation	Potential brood in egg stage	Emer.of new adults	Emer.of N.A.per sq.ft.	Loss in numbers	Loss in per-cent
			1931				
Slash small limbs & tops	16	1	21,888	480	30	21,408	97
Slash, large tops	8	2	10,944	1152	144	9,792	89
Fire scorched standing trees	10 1/2	3	14,364	441	42	13,923	95
Slash small tops	9	3	12,312	99	11	12,213	91
Fire scorched standing trees	11 3/4	4	16,074	904	77	15,170	94
Fire scorched standing trees	9	4	12,312	81	9	12,312	99
			1932				
Slash large tops	9	2	12,312	1062	118	11,250	91
Large slash	10	2	13,680	2430	243	11,250	82
Small slash	19	2	25,992	707	37	25,285	97
Large slash	14	3	14,616	1736	124	12,880	88
Large slash	10	3	10,440	1080	108	9,360	89
			1933				
Large slash 12" - 18"	28 2/5	1	19,425	5848	206	13,577	69
Fire scorched standing tree	6 2/5	3	6,681	1220	190	5,461	82

A summary of Table III shows that although there is a very large potential brood per square foot in the egg stage, a heavy loss in numbers occurs by the time emergence takes place. This loss averages 83 percent for the first generation, 90 percent for the second generation, 89 percent for the third and 97 percent mortality for the fourth generation. It will be seen in Table III that practically all types of slash and attacked standing trees were represented in the study and with the exception of some small standing fire-scorched trees, the small slash such as limbs and small tree tops sustained the heaviest loss in broods. These excessive losses are caused by a number of agencies which are enumerated in the following table.

Table IV.

AGENCIES RESPONSIBLE FOR LOSSES TO IPS OREGONI BROODS

Agency causing Losses	Generation	Developmental stage	Time of year	Host material	Range in % loss	Ave. % loss	Approx. % loss by agen.
Arachnida(mites)	1	Egg	April	Slash	69-97	83	52
Assoc.'d ins.	1	Larval,pupal	Apr.May	"			11
Disease	1	" "	" "	"			20
Mites	2	Egg	June	"	82-97	90	25
Assoc.'d Ins.	2	Larval,pupal adult	"	"			65
Mites	3	Egg	July	Slash & standing trees	82-95	89	20
Feeding activity excess adults	3	Larval	"	Standing trees			44
Assoc.'d Ins.	3	Larval,pupal adult	July & August	Standing Trees			20
Solar heat	3	" "	" "	Slash			5
Mites	4	Egg	August	Slash & standing trees	94-99	97	25
Feeding activity excess adults	4	Larval	Aug. & Sept.	Standing trees			20
Solar heat	4	Larval,pupal new adults	Aug.	Slash			5
Disease	4	" " "	Sept. & Oct.	Slash & standing trees			10
Assoc.'d Ins.	4	" " "	Aug.Spt. & Oct.	" "			10
Woodpeckers	4	" " "	Spt.Oct.	" "			16
Low temperature	4	Larval,pupal	Oct.Nov.	" "			11

The mortality caused by the various agencies as shown in Table IV is based on field observations and is only approximate because the activity of each agency is dependent upon climatic conditions. A cold, wet period during the larval and pupal stages of the first generation invariably results in a heavy mortality apparently from a fungus disease. The percentage of loss from associated insects and feeding activities of the excessive beetles also varies to a great extent, depending on weather conditions which also influence the rapidity of Ips oregoni brood development.

With appreciation of the heavy mortality occurring in all developing broods, it can be seen readily that the rapid building up and continuation of an infestation on an area is more a result of the ability of parent adults to continue activity during one or more seasons. The continued activity of parent adult beetles from each succeeding generation produces 10 or more extra broods in addition to the four or five generations developing in one season, thus making practically the same brood potential as would be secured from 14 generations. The continuation of an infestation on an area depends almost entirely on the amount and attractiveness of the available host material.

Ratio of Emergence to Attack

In determining the status of an Ips oregoni infestation, the ratio of attack to emergence becomes an important factor in determin-

ing the increase by brood development. The number of attacks per square foot of bark surface was found to vary considerable in different types of host material and during the different generations. The average secured in 1931 was 24 attacks per square foot for the first four generations and 26 for the fifth. The average number of egg galleries per attack was found to be three, containing three females and one male beetle or four in all. Applying this number of beetles to the number of attacks gives 96 parent adult beetles per square foot for the first 4 generations and 104 for the fifth. The average number of attacks per square foot for 1932 was comparable to 1931, but in 1933 for the first generation an average of only 12 attacks per square foot was recorded. The second, third and fourth generation attacks, however, reached the average of 24.

In Table V, examples are given of various types of host material from which the developing broods were obtained by the use of rearing cans. The number of attacks per square foot of bark surface was secured, and the average number of four parent adults applied to the number of attacks giving a basis of attacking beetle to compare with emergence by development.

Table V.

AMOUNT OF BROOD PRODUCED COMPARED WITH NUMBER OF ATTACKING BEETLES

Year	Gen	Type of host material	Actual No.att. per sq. ft bark surface	No.parent adults per sq.ft based on ave. per sq. ft.	Emer. New adults per sq.ft	Percent gain or loss per sq. ft
1931	2	Large slash 10-12"	19	76	144	89% increase
1931	4	Small fire-scorched tree	26	104	77	26% decrease
1931	4	Small fire-scorched tree	39	156	9	94% decrease
1932	2	Large slash	21	84	118	40% increase
1932	2	Small slash 3-6"	27	108	37	66% decrease
1932	3	Large slash 10-12"	24.4	98	124	27% increase
1933	1	Large slash 12-18"	12	48	206	329% increase

Table V shows that for the season of 1931 the only increase in new adults over the number of attacking adults was made during the second generation from large slash. With the small slash and small standing trees a decrease of from 26 to 94 percent was recorded. In 1932 all the larger slash producing the second and third generation broods showed an increase of from 27 to 40 percent, the only decrease recorded being in the small slash during the second generation. The greatest increase noted is shown in 1933 in large slash producing the first generation. The attacks resulting in this increase were made

by hibernating adults that had been subjected to temperatures as low as -30° F., during the winter and the shortage of adults to so reduce the number of attacks from 24 per square foot to 12 may have been caused by the extreme cold temperatures and also by delayed emergence of adults hibernating in stumps. With double the amount of food space available for the developing broods and a decrease in the number of predatory insects present, also due to the low temperatures, an increase of 329 percent occurred. However, the succeeding generations for 1933 resumed normal proportions.

Preferred Host Material

Throughout the ponderosa pine regions of Northern Idaho and Eastern Washington, the hibernating Ips oregoni adults emerging in April seem to prefer pine slash for their attacks. This slash may consist of large or small tops and limbs, or entire trees cut during the late fall, preceding winter, early in March, or during the period of attack. Even single pieces limbed or unlimbed lying on the ground or in piles such as fence posts, poles, cordwood or 16 inch wood piled or lying loose with the bark intact are subject to attack. Windfalls are attacked in the thinner barked portion and fire-scorched and badly damaged standing trees are selected when no slash is available.

When the host material is in piles such as poles, wood, etc., exposed to strong sunlight, the top portion is usually attacked first, producing the first generation broods and later the under side will be

attacked to produce the second generation. By the time this generation reaches maturity this type of host material has dried out to such an extent that it is no longer suitable for attack. Single pieces left lying in the sun are usually attacked but once producing one brood or generation. On areas where a number of small standing trees contain hibernating adults in the top portion and no slash is available close by, the first emerging adults will often attack and raise broods in the lower or green portion of the top killed trees. As the emergence becomes general with higher air temperatures, it is possible that long flights are made in search of slash. Flights of from 3 to 5 or more miles are indicated by the presence of isolated infestations that distance from the known source of supply.

Owing to its habit of excavating nuptial chambers and keeping them as well as the egg galleries free from frass, any flow of fresh pitch would be detrimental to the Oregon engraver beetles. Pitch flow, therefore, is undoubtedly a determining factor in the selection of host material and probably accounts for the preference for slash and damaged trees during the spring and early summer when the heaviest flow of pitch occurs in green trees.

If cutting continues on an area where the Oregon engraver beetles have concentrated, heavy attacks will continue in the slash for the second generation with decreasing attacks for the third and fourth generations as a decided preference is shown at this time for green or fire-scorched standing trees if this type of host material

is available in the immediate vicinity. Otherwise, many of the beetles will leave the area and fly in search of such trees.

If one or more of the older trees in an uneven-aged stand of ponderosa pine where no cutting has been done, should be attacked and killed by the Western pine beetle or lightning, these dead or dying trees very often attract Ips oregoni during the attack period for the third and fourth generations, drawing them into the area and resulting in a kill of the smaller surrounding trees sometimes numbering into the thousands. Small trees felled and left intact lying among a stand of reproduction, piling freshly cut wood or slash near or against green standing trees, or the mechanical injury to trees in camp sites will attract Ips oregoni beetles to the locality causing infestations of varying intensity resulting in the death of smaller trees or late season attacks by hibernating adults in the tops of larger trees.

When wood and tie cutting or logging operations are continued yearly on an area, a continual infestation of the Oregon engraver beetle may be expected for as long as the preferred type of host material is available. Ground fires in pure reproduction or mixed stands of ponderosa pine usually result in varying numbers of trees with severe injury either to the crown or root collar or both, and this type of host material is especially attractive to the Oregon engraver beetle. Intensive fire and insect studies made by the

writer show that Ips Oregoni infestations will increase on an area as much as 2440 percent following a severe ground fire. This large increase diminishes very rapidly the second year and the third year shows either normal conditions or no evidence of the beetles on the area. The most severely damaged trees up to 14" DBH are selected first. Later attacks are concentrated on the remaining most severely damaged class, and as soon as this supply is exhausted the burn no longer is attractive to the beetles because the remaining trees are either on the way to recovery or dead from the effects of the burn.

The construction of trails, roads and highways through forested areas results in large amounts of slash material and injured trees which, in the ponderosa and lodgepole pine types, are suitable host material for the Oregon engraver beetle. When this material is selected for attack, a rapid building up of the infestation occurs resulting in numerous small green standing trees being killed along the edges of the construction. Infestations of this nature usually follow the construction work each season in search of fresh host material.

There are numerous examples of the Oregon engraver beetle returning to the same area late in the season year after year to attack small groups of trees on an open sunny exposure along the edges of stands of ponderosa and lodgepole pine reproduction. These group killings contain old attacked trees which have fallen and are

in all stages of decay and disintegration, and standing trees showing attacks from three or four years old to those containing live adults and broods. Each year's killing may consist of from one to twenty trees or more.

CONTROL

Artificial Control

An intensive study of the life history of Ips oregoni, has shown that the continued activities of parent adult beetles throughout the season has as much bearing on the continuation of infestations as the increases resulting from the emergence of new adults. Therefore, in order to be effective, artificial control measures conducted against this insect must destroy the parent adult beetle as well as the developing broods. It has been found that the burning of infested material accomplishes this most effectively, providing the material is treated at a time calculated to destroy the adult beetles. A study of the habits of this bark beetle shows that the parent adults remain in the newly attacked material until the developing broods reach the first new adult stage, at which time the parent adults emerge and attack new host material. To burn the infested material while the developing broods are in the egg or young larval stage, insures the most success. In considering control for the second or third generations, quick action would be necessary as it has been found that during these periods parent adults will be emerging in from 18 to 28 days from time of attack and new adults from 24 to 34 days. Examination of infested

material before control is necessary to prevent burning after the material has been abandoned by the bark beetles.

In considering control by burning for any type of host material, care is necessary in order to prevent the scorching or injuring of green standing trees because scorched or badly injured trees from 3 to 14 inches D.B.H., are attractive to this beetle, especially for attacks for the third and fourth generation broods. Individual trees or groups containing overwintering or hibernating adults can be cut and burned any time after heavy frosts in the fall usually early in November until the end of freezing temperatures in the spring, or not later than the middle of March. The same date applied to stumps containing hibernating adults which can be destroyed by heavily scorching or burning the bark. For areas in high elevations in the lodgepole pine type where two or possibly three generations of Ips oregoni develop during a season, examinations at short intervals would best determine times for control by burning.

Piled or unpiled cordwood, 16 inch wood, fence posts and rails cut from green timber with the bark intact should be removed as soon as cut to a considerable distance from the cutting area and not piled against or close to standing green trees.

Natural Control

Owing to its habit of excavating open egg galleries, the Oregon engraver beetle is subject to association with many other

Arthropods which act in the capacity of guests, scavengers, predators or parasites. There appears to be no escape from these associates, as many of the species overwinter in the adult stage with the developing broods and hibernating Ips adults. Those that overwinter in the larval from transform to new adults, usually in time to follow up the late attacks for the first Ips generation broods.

A complete list of all the Arthropods found in association with Ips oregoni in ponderosa pine in northern Idaho is included, as well as a brief discussion of those determined as the most beneficial in the natural control of the Oregon engraver beetle. All of the species on the list have been examined by specialists in the U. S. National Museum in Washington, D. C., and correct names given as far as known. Many of the species are undescribed and in some instances only the genus can be given for the present. This list is also offered as a contribution toward the fauna of the ponderosa pine.

In the list, the order Coleoptera ranks first with 69 species, Hymenoptera next with 9, Hemiptera 8, Diptera 6, and Arachnida 4, making a total of 96 species. In order of their economic importance, however, the Arachnida (mites) rank first, two species being found to be very beneficial in destroying large numbers of Ips oregoni eggs in all generations and broods.

Arachnida

Tarsonemus sp.

This small mite feeds on the eggs of Ips oregoni and is one

of the most beneficial agencies causing the mortality of this beetle. As soon as contact with the Ips egg is secured the female mite punctures the chorian and begins feeding on the contents. As this liquid is imbibed, the mite begins a gradual swelling, finally ending in a spherical shape and resting on its dorsal surface. As soon as the feeding is completed and while in the dorsal position, eggs are laid one at a time and form in a cluster around the body of the female mite. As soon as oviposition is complete, the female mite is nearly surrounded by the egg mass numbering from 42 to 65 eggs held together by a glutinous substance. The eggs are spherical in shape and measure approximately .1 m.m. in diameter, an entire cluster of 65 eggs measuring slightly less than one millimeter in diameter.

During the warm summer weather the eggs hatch in a few days and the young mites soon begin wandering through the egg galleries of the Oregon engraver beetle. One female mite per Ips oregoni egg is the usual number, but occasionally two and as many as four have been found feeding on one egg.

As these mites are so small and move about in Ips egg galleries and brood chambers so rapidly, no accurate count of the number per square foot of bark surface was secured. Both the adults and young mites obtain transportation by clinging by their mouth parts to the elytral declivity or ventral region of adult Ips beetles. Seventy-seven Ips oregoni adults collected from one square foot of bark surface carried 2265 of these mites on their bodies making an average of 29.4

mites per beetle. The largest number found on one beetle was 42. Their method of self-preservation, that is, securing transportation from one host tree to another by clinging to the adult Ips or associate beetles when in the act of leaving the host, is undoubtedly an inherent trait of these mites because soon after hatching, they lost no opportunity to attach themselves to an Ips adult if it showed any indication of emerging. If the Ips adult shows an indication to remain in the bark, the mites will remove themselves and resume their activity of running about through the Ips egg galleries or brood chambers. A few of these mites have been found in abandoned trees representing some that no doubt failed to secure transportation at the proper time. Hibernating Ips oregoni adults removed from the inner bark of small stumps early in April, had many of the mites fastened to their elytral declivity which would indicate that some of the mites possibly overwinter clinging to the bodies of the beetles. It seems quite probable that some of the female mites gain access to the Ips eggs by clinging to the female beetles until the egg niche is cut, when they could immediately occupy the chamber.

All egg laying activities of the Oregon engraver beetle are subject to attack by mites beginning with eggs for the first generation broods in April and continuing on through the season. The percent of loss to Ips eggs from the mites varies a great deal not only in individual egg galleries, but also in the various generations. Egg galleries containing eggs of the first generation have been found to

have sustained a 52 percent loss from the mites and galleries during the fifth generation in 1931 sustained a 50% loss. Varying degrees of loss of from 5 to 76 percent have been found during the second, third and fourth generation. A 20 percent mortality to all generations would be a fair estimate for this species of mite.

Parasitus sp.

This species is the largest mite of the three genera found in association with the Oregon engraver beetle. These mites, both in the nymph and adult stages secure transportation by secreting themselves under the elytra of the adult Ips beetle. The maximum number found on one adult Ips beetle being nine, seven under one elytron and two under the other and the average for all Ips adults examined was two. These mites were found to average one per Ips attack which would equal 24 per square foot of bark surface. This species of mite destroys the Ips oregoni eggs by gaining entrance into the egg niche, possibly through a small aperature caused by a shrinkage of the frass plug or by concealment in the niche before the egg is laid, as many of the mites were found along with the collapsed egg in the niche with the frass plug still in place. The total amount of mortality caused by this species of mite is not known, but is believed to vary from 2 to 5 percent.

Coleoptera

Cleridae

Two species of Clerid beetles were found to be very beneficial

in destroying both the parent adults and developing broods of the Oregon engraver beetle.

Enoclerus sphegeus Fab. A few larvae of this species overwinter in the brood chambers of Ips oregoni, the balance hibernating in the duff at the base of attacked trees. These clerid larvae transform to new adults in time to search out and deposit eggs in attacked material containing Ips oregoni first generation broods. From 3 to 5 E. sphegeus larvae are usually found per square foot of bark surface with the first and second generations of Ips broods, and 2 to 3 per square foot with the third and fourth generations. The adult clerids capture and devour Ips adults on the outer bark surfaces, particularly during the attack and emergence periods. The greatest damage, however, is caused by the clerid larvae which are voracious feeders, able to chew through the pupal cell walls and are thus able to secure the Ips broods in all stages of development.

Enoclerus lecontei Wolc. This species next in importance to sphegeus, feeds in the same manner and makes its first appearance in the developing broods of the third generation of Ips oregoni. An average of four larvae per square foot of bark surface was found for this species, both for the third and fourth Ips generations.

Ostomidae

Temnochila virescens var. chlorida Mann. This beetle is similar in feeding habits to the clerid beetles but overwinters both in the adult and larval stage. It is one of the first predators present on

new Ips attacked material in the spring and continues its activity throughout the season. The Temnochila larvae average two per square foot of bark surface for all Ips generations.

Cerambycidae

Monochamus maculosus Hald., M. oregonensis Lec. & M. obtusus Csy. These three species of wood borers overwinter in the larval stage, and transformation to adults takes place in time for some eggs to be deposited in slash containing the second generation broods of the Oregon engraver beetle. The third and fourth generation Ips broods are affected most by the feeding activities of the Monochamus larvae which destroy the Ips brood chambers and a large amount of the available food supply causing starvation to many of the developing Ips larvae.

Colydidae

Aulonium longum Lec. This beetle overwinters in the adult stage in association with hibernating Ips oregoni adults, emerges with them in April and becomes an early associate in attacked material. Some of the Ips oregoni broods are destroyed while in the larval and pupal stages by the larvae of A. longum which average 24 per square foot of bark surface for all Ips oregoni generations.

Histeridae

Platysoma punctigerum Lec. The adult of this species overwinters with hibernating Ips oregoni, emerges in time to become an

early associate with the first generation attacks, and are found in the egg galleries and pupal cells of the developing broods throughout the season. Both the adult and larvae are predacious and average two per square foot in all generations.

Hymenoptera

Pteromalidae

Pachyceras eccoptogasteri Ratz. This is the most important primary parasite of the Oregon engraver beetle. The female gains entrance to the egg galleries through the entrance hole in the nuptial chamber and then works its way through any available crevice or tunnel between the bark and wood. Eggs are laid only on Ips prepupal larvae or pupae and only a single egg is usually deposited on the dorsal side of the Ips larva back of the head capsule and in a corresponding position on the pupae. The egg hatches in a few days and the larva of the parasite begins feeding on its host and develops rapidly. (See Plate 7.) In laboratory rearings transformation from newly hatched larvae to imagines was completed in from 17 to 20 days. This rapid development makes it possible for the newly transformed adult females to parasitize some of the later developing Ips oregoni brood in the same host material. Parasitization from this species occurs in all generations and results in a loss of from 3 to 5 larvae per square foot in the first generation and 20 to 30 per square foot in the second, third and fourth generations. This parasite overwinters in the larval stage.

Braconidae

Coeloides dendroctoni Cush. This species is a primary parasite on Ips oregoni prepupal larvae and ranks next in importance to the preceding species. Adults transforming from overwintering larvae in cocoons, emerge in time to start attacks on the prepupal larvae of the first generation of Ips oregoni and follow up throughout the season. This species reaches its maximum importance during the third generation period of the Oregon engraver beetle, at which time as many as 16 cocoons per square foot of bark surface were found.

Ipocoelinus sp. This species, belonging to a genus of which no North American species have been described, was found to be a parasite of Ips oregoni adults. The method of attack and egg laying has not been observed, but the small larvae feed internally on the viscera of the beetle and on becoming full grown entirely fill the abdominal cavity. By the time the parasite reaches the adult stage, the sclerotized shell of the Ips beetle separates between the pro and mesothorax and the parasite emerges from this opening. This parasite caused more mortality to adult Ips oregoni under the bark than any of the other associated insects observed. This species overwinters in the larval stage in its host.

Vespidae

Vespula diabolica (Saussure) var. feruaIdi (Lewis) Common Yellow Jacket. This insect, while not an associate beneath the bark, has an important part in causing mortality of Ips adult beetles.

particularly the male beetles during the attack period when they are crawling about over prospective host material and during construction of the entrance hole. Female Ips oregoni adults are also captured from the outer bark surface and new adults upon emergence.

Diptera

Medetera aldrichi Wheeler. The adult is dark grey in color and varies from four to five m.m. in length. The female searches out trees newly attacked by the Oregon engraver beetle and travels up and down over the outer bark surface in a rapid manner searching out suitable crevices in which to deposit eggs. Soon after hatching the larvae work their way into the inner bark and begin feeding on any larvae with which they come in contact. Their method of feeding is to pierce the cuticle of their hosts with sharp mandibular sclerites through which they extract the larval fluids, finally reducing the host larvae to nothing but the outer skin. In the third and fourth generations Ips broods, Medeterus larvae usually average 3 per square foot of bark surface.

Hemiptera

Of the 8 species of Hemiptera found in association with Ips oregoni, only one was observed that is considered of economic importance.

Xylocorus sp. This undescribed species of Xylocorus was the most abundant of the Hemiptera found in the Ips association. They overwinter in the nymph stage in the material which contained the

third and fourth generations of Ips oregoni, and emerge as adults in time for the females to deposit eggs in the first Ips attacks in April. The female secures access to the developing Ips broods through the open egg galleries and crevices in the inner bark. No observations of oviposition by the female Xylocorus were secured. The first indication of their presence is the small bright red nymphs seen moving rapidly about through the Ips brood chambers and egg galleries. Nymphs less than one-sixteenth of an inch were observed feeding on Ips larvae as well as full grown larvae of Hymenopterous parasites. Owing to the rapidity of Ips oregoni development, all later feedings of the Xylocorus nymphs would be concentrated on other associated larvae as considerable time is required for their full development. Small nymphs collected in April required two months to reach three-eighths of an inch in length at which time they made their third and last moult while in captivity. These nymphs as well as a number of others were supplied with Ips larvae as a source of food. Their method of feeding is to raise their long sharp beak, approach the intended victim cautiously and when within striking distance pierce the larval skin with the tip of their beak, brace their body firmly and begin drawing out the body juices of the larva. The duration of feeding varies from one to three minutes. Ips larvae dry rapidly after one or two of these feedings and are no longer suitable as food. An average of four nymphs per square foot of bark surface was found for all Ips oregoni generations.

Aves

A discussion of the natural control of the Oregon engraver beetle would be incomplete without mention of the economic value of woodpeckers in destroying large numbers of the adult Ips beetles as well as their developing broods. The two following species of woodpeckers were found to be very beneficial.

Dryobates villosus monticola Anthony. (Rocky Mountain Hairy Woodpecker) The Rocky Mountain Hairy Woodpecker being the most numerous of the two species, is also of the greatest value in destroying large numbers of Ips oregoni adults and their developing broods in standing trees. Only in rare instances have they been found working on infested slash. This species of woodpecker usually begins to work on trees containing Ips oregoni fourth generation broods during the latter part of August and continues all through the months of September and October and occasionally throughout the balance of the winter. By the time the adult birds begin stripping the Ips trees, their young of the current season have attained sufficient growth and strength to assist in the destruction of the Ips broods, thus greatly increasing the value of this species of woodpecker. Both large and small groups of green and fire-scorched infested trees are located by the woodpeckers. If the Ips broods are plentiful in a tree the entire bark surface covering the extent of the attack will be removed by the woodpeckers, but on lightly attacked trees only the thickly populated portions are stripped of bark. As stated in the seasonal

history of the Oregon engraver beetle, many excess Ips beetles congregate in standing trees containing the third and fourth generation developing broods. Large numbers of these adult beetles are thus destroyed by the feeding activities of the woodpeckers. Top-kills on the large ponderosa pine are also visited by this species of woodpecker resulting in the destruction of many overwintering and hibernating Ips oregoni adults.

Picoides tridactylus dorsalis (Alpine Three-toed Woodpecker) This species of woodpecker is also valuable in destroying large numbers of Ips adults and developing broods in standing trees, its range being confined more to the higher elevations and denser stands on slopes and bench lands. It has not been observed working on ponderosa pine slash.

ANNOTATED LIST OF INSECTS AND ARACHNIDA IN ASSOCIATION WITH IPS OREGONI

Coleoptera

	Abundance per sq. foot of bark		Value as a controlling agt of Ips oregoni broods
	Larvae	Adults	
STAPHYLINIDAE			
Sacium lugubre Lec.		1	Not known.
Eleusis nigrella (Lec.)		1	" "
Xantholinus cephalus Say		2	" "
Placusa sp.	25	2	" "
Leptusa sp.	13	2	" "
HISTERIDAE			
Platysoma punctigerum Lec.	2	2	Predacious in larval and adult form.
Plegaderus nitidus Lec.		1	Not known.
MELYRIDAE			
Malachius sp.		1	Not known.
Listrus sp. (near senilis Lec.)		Rare	" "
Listrus montanus Csy.		"	" "
Eurelymis atra (Lec.)		"	" "
CLERIDAE			
Enoclerus sphegeus Fab.	3		Predacious in larval and adult form.
Enoclerus lecontei Wolc.	4		"

	Abundance per sq. foot of bark		Value as a controlling agt of Ips oregoni broods.
	Larvae	Adults	
OTHNIIDAE			
Othnius lugubris Horn	1		: Predacious in larval : and adult form.
PEDILIDAE			
Pergetus campanulatus Lec.	Rare		: Not known
PHTHIDAE			
Lecontia discicollis (Lec.)	"		: " "
BUPRESTIDAE			
Chalcophora angulicollis (Lec.)	Unknown		: No value
Dicerca tenebrosa (Kby.)	"		: Not known
Buprestis aurulenta L.	"		: No value
Buprestis laeviventris (Lec.)	"		: Probably in larval stage : destroying Ips larvae food : supply.
Chrysobothris dentipes (Germ.)	"		: "
OSTOMIDAE			
Corticotomus caviceps (Fall)	Rare		: Not known.
Temnochila virescens var. chlorida (Mann)	?	1	: Predacious as larva & adult.
Tenebroides occidentalis Fell	1	1	: Not known.
NITIDULIDAE			
Epuraea avara (Rand.)	1	1	: Not known.

	Abundance per sq. foot of bark		Value as a controlling agent of Ips Oregoni broods.
	Larvae	Adults	
NITIDULIDAE (Cont'd)			
Soronia guttulata (Lec.)	Rare		: Not known.
Glischrochilus quadrisignata (Say)	"		: " "
Glischrochilus vittatus (Say)	"		: " "
Rhizophagus sculpturatus Mann	1	1	: " "
EROTYLIDAE			
Dacne utesna Csy	Rare		: " "
TENEBRIONIDAE			
Hypophloeus parallelus Melsh.	3	5	: Predacious as larva & adult.
PTINIDAE			
Ptinus sp.	Rare		: Not known
CRYPTOPHAGIDAE			
Henoticus serratus (Gyll.)	"		: " "
COLYDIIDAE			
Lasconotus complex Lec.	4	2	: Probably predacious as larvae.
Lasconotus subcostulatus Kraus	20	19	: " " " "
Aulonium longum Lec.	24	3	: Predacious as larvae & adults.
Deretaphrus oregonensis Horn	Rare		: Not known
ANOBIIDAE			
Ernobius sp.	"		: Not known.

	Abundance per sq. foot of bark		Value as a controlling agent of Ips oregoni broods.
	Larvae	Adults	
BOSTRICHIDAE			
Stephanopachys sobrinus Csy.	Rare		Not known
Cerambycidae			
Ergates spiculatus Lec.	Unknown		None
Asemum atrum Esch.	"		Not known
Stenocorus lineatum Oliv.	"		Probably in larval form.
Semanotus nicoles White	"		Not known
Callidium antennatum var. hesperum Csy.	"		" "
Phymatodes dimidiatus (Kby.)	"		" "
Neoclytus muricatulus (Kby.)	"		" "
Monochamus maculosus Hald	2		Destroy Ips larvae food supply.
Monochamus oregonensis Lec.	2		" " " " "
Monochamus obtusus Csy.	2-4		" " " " "
Acanthocinus obliguus Lec.	Rare		Not known
CURCULIONIDAE			
Gelus californicus (Lec.)	"		Not known
Cylindrocopturus longulus (Lec.)	Unknown		Not known
Cossonus ponderosae Van D.	"		Not known
SCOLYTIDAE			
Dendroctonus brevicomis Lec.			Breeds in association.
Dendroctonus monticolae Hopk.			" " "

	Abundance per sq. foot of bark		Value as a controlling agent of Ips oregoni broods.
	Larvae	Adults	
SCOLYTIDAE (Cont'd)			
Dendroctonus valens Lec.			Breeds in association.
Hylurgops subcostulatus (Mann.)			None.
Gnathotrichus retusus (Lec.)			"
Pityophthorus confinus Lec.			Breeds in association.
Pityophthorus idoneus Blkm.			None.
Pityophthorus confertus Sw.			Breeds in association.
Pityophthorus retusus Lec.			" " "
Pityogenes carinulatus (Lec.			" " "
Ips emarginatus (Lec.)			None.
Ips sp. near latidens	Rare		Breeds in association.
Ips integer (Eich.)	50-100	10-24	" " "
Ips sp. near longidens	Rare		" " "
Ips sp. near interruptus	"		" " "
Orthotomicus caelatus Eichh.	"		" " "

Hymenoptera

	Abundance per sq. foot of bark		Value as a controlling agent of *Ips oregoni* broods.
	Larvae	Adults	
Pachyceras eccoptogastri Ratz.	*I.o.* 1st gen: 4 3,4 gen-25	*I.o.* 2,	Parasitic on *I.o.* prepupal larvae
Coeloides dendroctoni Cush.	*I.o.* 3 gen 14		"
Meteorus hypophloei Cush.	Unknown		Probably parasitic on *I.o.* larvae
Ipocoelinus sp.	*I.o.* 3,4 gen.-4		Parasitic on Ips adults
Leptacis n.sp.	Unknown		Not known.
Hemiteles sp.	"		" "
Passaloecus sp.	"		" "

Hemiptera

	Abundance per sq. ft of bark	Value as a controlling agent of Ipsoregoni Broods
Xylocaris sp.	Nym. 4	Predacious in the nymph stage.
Lyctocoris doris Van D.	Unknown	Not known
Crophius impressus Van D.	"	" "
Corizus indentatus Hambl.	"	" "
Eremocoris obscurus Van D.	"	" "
Aradus persimilis Van D.	"	" "
Aradus debilis Uhler.	"	" "
Brachymena hoppingi Van D.	"	" "

Diptera

	Abundance per sq. foot of bark Larvae	Value as a controlling agent of Ips oregoni broods.
Lonchaea hirticeps Ald.	4 : 3&4 I.o. gen.s	Probably Predator in larval stage.
Medetera aldrichi Wheeler	3 : 3&4 I.o. gen.s	Predator in larval stage.
Palloptera terminalis Lw.	Unknown	Not known.
Xylota pigra Fab.	"	" "
Cecidomyidae sp.	"	" "
Orthocladius sp.	"	" "
Zabrachia sp. near polita	"	" "
Pseudatrichia flaviceps Cog.	"	" "

Arachnida
(Mites)

	Abundance per sq. ft of bark	Value as a controlling agent of Ips oregoni broods.
Parasitis sp.	24	Important as a predator on I.o. eggs.
Tarsonemus sp.	As many as 2265 from: 1 sq. ft.	"
Alicus sp.	Unknown	Not known.
Uropoda sp.	"	" "

SUMMARY AND CONCLUSIONS

Ips oregoni, originally described in 1868 and now commonly known as the Oregon engraver beetle, is one of the most destructive of the so-called secondary bark beetles.

In the course of a study of this bark beetle in the vicinity of Coeur d'Alene, Idaho, the writer devoted three full field seasons and part of a fourth in securing information relative to its habits and seasonal history. Field observations were supplemented by laboratory rearings in cages and rearing cans.

The range of the Oregon engraver beetle is very extensive and is the same as that of the ponderosa pine which extends from northwestern Canada to Mexico and from the Dakotas to the Pacific Coast. Other trees in which this beetle is known to breed are lodgepole, Jeffrey, sugar and Digger pines. It has also been collected from two species of spruce.

Developmental stages comprise egg, larva, pupa and new adult. Three instars occur during the larval stage. Newly formed adults are yellow brown on color, with a final development of shiny black. The adult beetles are cylindrical in form and average 4.1 m.m. in length and 1.6 m.m. in width. Both the male and female beetles have four spines on the margin of the elytral declivity, the male being readily distinguished from the female by the greater length of the third spine.

The attack is made by the male beetle which constructs a small cell between the bark and wood known as the nuptial chamber. Attacks per square foot of bark surface vary from 11 to 49 with a general average of 24. The female beetles seek out the attacks and the first matings occur in the nuptial chamber. Egg gallery construction soon follows and oviposition usually starts after 3/8 inch of gallery is completed. The number of females per attack determines the number of egg gallery branches which vary from 1 to 7 with an average of 3 for all attacks.

The average sex ratio in the attacking beetles was found to be 3 females to 1 male, but among the emerging new adults there were only 1.2 females to 1 male. Mortality to male beetles during the attack period may have some effect on the ratio of 3 to 1 in attacks.

Egg gallery construction follows the grain of the wood and larval mines are constructed at right angles to the egg gallery. The average total length of egg gallery per attack was found to be 10½ lineal inches for the first three generations and 7½ inches for the fourth or fifth when present.

In seasons of abnormally high temperature and diminished rainfall, five complete generations can develop during the growing season, but during seasons of normal temperature and rainfall, only four are produced. The average developmental period or length of seasonal activity for four seasons was found to be 180½ days.

The lineal feet of egg gallery construction per square foot was found to vary considerably, but the average of 21 lineal feet was quite

constant for the normal four generations per season. The average number of eggs per lineal foot of egg gallery was found to be 72. Applying this egg average to the occupied egg gallery gives an average potential brood per square foot of bark surface of 1368. A very heavy mortality was found to occur from the egg stage to emergence. Rearing experiments showed this loss to average 83 percent for the first generation, 90 percent for the second, 89 for the third and 97 for the fourth generation. The results of the study showed this heavy mortality to be caused by associated predacious and parasitic Arthropods, disease, feeding activities of excess adults, solar heat, low temperatures and woodpecker work.

An excess number of adult beetles was often found in attacks for the third and fourth generation broods. These beetles appeared to be resting and feeding. This crowded condition was usually found to occur during periods of maximum air temperatures from 82° to 92° F., and caused a loss of the normal food supply for the developing broods.

The hibernation period of Ips oregoni begins with the advent of heavy frosts, usually the latter part of October. The adult beetles hibernate in trees containing the last generation broods, the larger slash, freshly cut stumps, and in the egg galleries of the western pine beetle. The ability of adult beetles to continue from one season to another by hibernating during the winter accounts to a great extent for the continued presence of large numbers of Ips

oregoni beetles throughout its range.

The ratio of emergence to attack showed that only the larger slash produced an increase in new adults over the number of parent adults which made the attacks. This increase varied from 27 to 40 percent. A decrease of from 26 to 94 percent was recorded for small slash and standing trees.

In the selection of host material, the hibernating adults emerging in April seem to prefer pine slash for their attacks. This slash may consist of large or small tops and limbs, or entire trees cut during the late fall, preceding winter, early in March or during the attack period. Fence posts, poles, cordwood, or 16 inch wood piled or lying loose with the bark intact are subject to attack. Windfalls are attacked in the thin-barked portion, also fire-scorched and dsmaged trees. Piled material such as poles, posts and wood is usually attacked first on the upper portion producing first generation broods and later the under side will be attacked to produce the second generation. Beginning with attacks for the third generation broods, a preference is shown for standing trees.

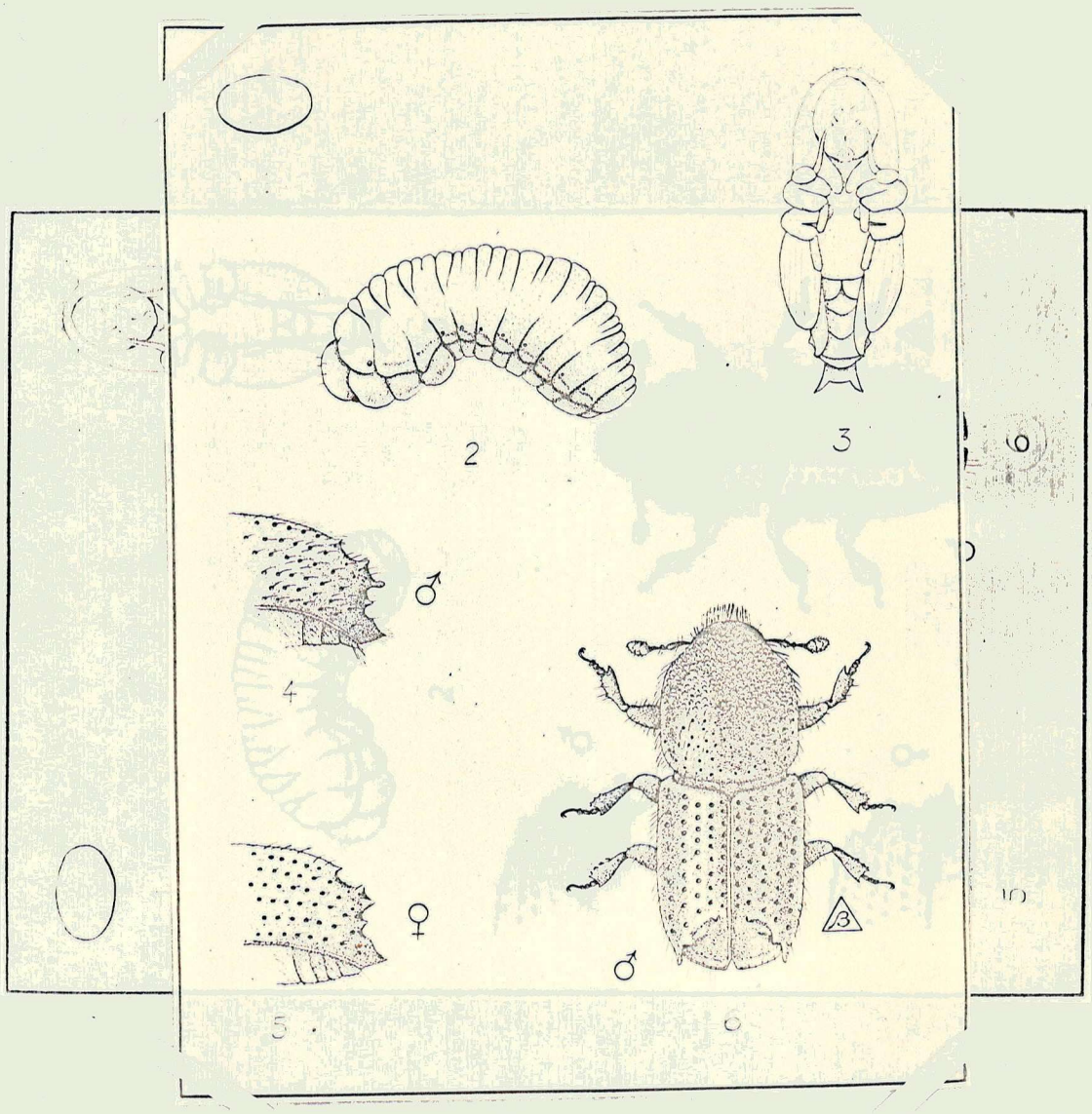
The Oregon engraver beetle will return to the same area late in the season year after year to attack small groups of trees on an open sunny exposure along the edges of stands of ponderosa and lodgepole pine reproduction.

In order to secure the most effective results from artificial control measures against this insect, the adult beetles must be

destroyed as well as the developing broods. It has been found that the burning of infested material accomplishes this most effectively, providing the material is treated at a time calculated to destroy the adult beetles. The treating of infested trees containing overwintering broods and hibernating adults prior to emergence in April, and material containing first generation attacks insures the most effective results. Considerable care is necessary in this method of control to avoid scorching or otherwise damaging green standing trees. Owing to its flight habits, there is no positive assurance that after an infested area has been controlled, that it will not be reinfested if additional host material becomes available.

Owing to its habit of excavating open egg galleries, the Oregon engraver beetle is subject to association with many other Arthropods which act in the capacity of guests, scavengers, predators or parasites. A complete list of all the Arthropods found in the association includes 69 species of Coleoptera, 9 species of Hymenoptera, 8 species of Hemiptera, 6 species of Diptera and 4 species of Arachnida making a total of 96 species. Of this total, 15 species were observed to be very beneficial in the natural control of the Oregon engraver beetle. Two species of woodpeckers were also found to be very beneficial in destroying large numbers of Ips oregoni adults and developing broods from standing trees.

Plate 1



Photograph of six enlarged drawings showing four stages of Ips oregoni life history and characteristic spines on elytral declivity.

Fig. 1 - Egg
Fig. 2 - Larva
Fig. 3 - Pupa
Fig. 4 - Elytral declivity of male beetle showing the prominent third spine.
Fig. 5 - Elytral declivity of female beetle.
Fig. 6 - Adult male beetle

Plate 2

Six sections of inner bark layer near actual size showing six attacks by the Oregon engraver beetle, and various shapes of the nuptial chamber caused by the arrangement of egg gallery construction.

a. - Entrance Hole.
b. - Nuptial Chamber.
c. - Egg gallery.
d. - Eggs in position in egg niches.

Plate 3

Two views of the top portion of two small ponderosa pine stumps with a section of the bark removed. In the areas included in the circles can be seen a grouping of short feeding tunnels, a few still containing Ips oregoni adults. These pictures were made in April and immediately on removal of the bark, the adults began moving in all directions and only a few remain in the picture. These adults, still in the yellow-brown color stage, represent hibernating adults developing from fourth generation broods in standing trees nearby.

Plate 4

13/16 natural size

A near life size view of completed Ips oregoni egg galleries showing egg niches and eggs in position and the relation of one attack to another in lightly attacked material. These attacks show the relation of the openings of the egg galleries to the entrance holes marked with the letter E. This arrangement shows the advantage of disposing of the frass or borings when they are dropped from above into the nuptial chamber or when raised up from the lower galleries.

Plate 5

Pinus ponderosa slash showing a heavy attack by Ips oregoni and illustrating attacks with more than four egg galleries resulting in a crowded condition for developing broods.

Plate 6

Two views of pinus ponderosa bark from green standing trees containing fourth generation Ips oregoni broods in the larval stage. The enclosed areas show the effects of feeding by excess adult Ips beetles in destroying the food supply of the developing Ips larvae.

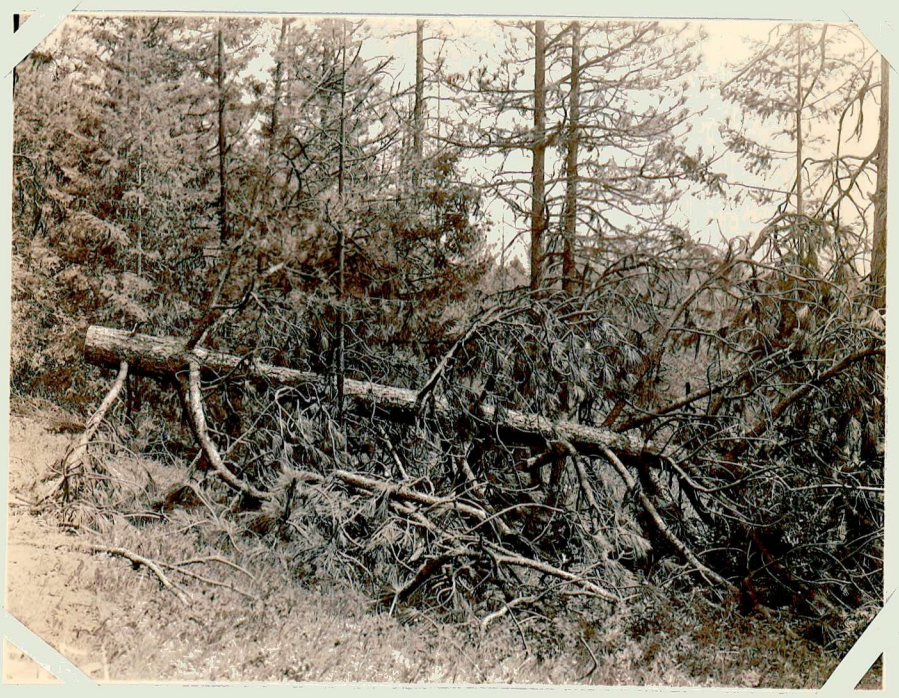
Plate 7

Small section of ponderosa pine bark near actual size showing the effects of parasitization of Ips oregoni broods by the Hymenopterous parasite Pachyceras eccoptogastri Ratz. The Ips oregoni pupal cell marked with an X shows a partly grown hymenoptera larva feeding on its host, an Ips pupa. The three pupal cells enclosed in circles show the larva of the parasite at the cessation of feeding, prior to pupation.

Plate 5

View in ponderosa pine stand showing usual type of slash resulting from logging operations. The upper unlimbed section represents typical host material for attack by the first and second generation Ips oregoni broods. Subcortical temperatures from the top surface of this type of slash exposed to strong sunlight have been found to reach 106° F., with an air temperature of 96° F., resulting in no apparent loss to the developing broods.

Plate 9



View showing a type of ponderosa pine slash often left on logging and woodcutting areas. This form of slash will attract Ips oregoni and when harboring the first or second generation attacks, average broods will result. When attacked later in the season during the hot weather, subcortical temperatures of the inner bark surface on the top portion of the slash will reach as high as 125° F., with an air temperature of 96° F. This excessive heat causes a rapid drying out of the inner bark and also results in solar control of a portion of the broods developing in this particular area.

Plate 10

View showing a group of 21 ponderosa pinas from four to ten inches D.B.H., attacked and killed by the Oregon engraver beetle. Logging operations were conducted on this area, creating considerable large slash from which many Ips beetles emerged.